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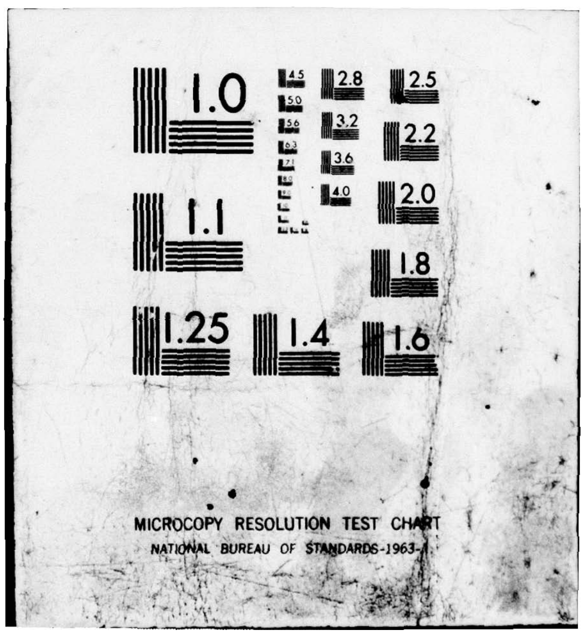
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FORTRAN PROGRAM OBLIQUE IN PL-FORMAT USER'S MANUAL

by

Daniel T. Valentine

STEVENS INSTITUTE OF TECHNOLOGY · PER ASPERA AD ASTRA · A.D. 1870

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INTRODUCTION

This manual accompanies the program listings and a magnetic tape containing two files, one of program OBLIQUE and one (the second) of program OBLIQ02. ~~The theoretical procedure behind~~ the computer programs and its limitations are described in detail in Reference 1. The programs OBLIQUE and OBLIQ02 plus the program PPEXACT are used in the procedure described herein to compute the blade bending moments of a propeller operating in an oncoming flow inclined to the propeller shaft. The theoretical analysis leading to and the operation of PPEXACT have been described by Tsakonas, et al[2,3]. The purpose of this manual is to present sufficient information on the organization of the programs, descriptions of the input and output, and description of the input to the sample calculation presented in Reference 1, so that an engineer with a knowledge of FORTRAN may execute the procedure successfully.

ORGANIZATION OF PROGRAMS OBLIQUE AND OBLIQ02

The program was designed to solve an integral equation, Eq. (25) in Reference 1, namely,

$$\iint_S \Delta P_o^{(0)} K_1' \, ds + \iint_S \Delta P_o^{(2)} K_1'' \, ds = \iint \Delta P_1^{(1)} K_o \, ds \qquad (1)$$

where K_o is the kernel of the integral equation for the shaft-frequency harmonic loading described by Tsakonas, et al[2] and programmed in PPEXACT.[3] Program OBLIQUE computes K_1', multiples by $\Delta P_o^{(0)}$ and performs the surface integration over all the propeller blades. Program OBLIQ02 computes K_1'', multiples by $\Delta P_o^{(2)}$ and performs the surface integration over all the blades. Brief descriptions of the terms in (1) are given next; however, for details on the equations programmed, the reader is referred to Valentine.[1]

The factors K_1' and K_1'' inside the integrals on the left-hand-side of (1) are geometric quantities related to the deviations from circular helicoidal stream surfaces of the shed helicoidal flow field behind a propeller in an inclined flow. The $\Delta P_o^{(0)}$ and $\Delta P_o^{(2)}$ factors are the steady and second harmonic of blade loading due to the mean and second harmonic of the circumferential spatial variation of the oncoming flow into the propeller, respectively. The subscript o implies that these quantities are computed by the procedure described in References 2 and 3 utilizing PPEXACT. Therefore, the propeller model used to compute $\Delta P_o^{(0)}$ and $\Delta P_o^{(2)}$ neglects the oncoming flow inclination. Equation (1) is of order ψ, the shaft inclination angle, which is assumed to be small. The propeller is assumed to be lightly-loaded. The relatively large shaft frequency component of the measured circumferential variation of the tangential velocity into the propeller disk inclined to the oncoming flow produces a shaft frequency loading $\Delta P_o^{(1)}$. Thus, Eq. (1) is an additional contribution to the shaft frequency loading due to the distortion on the shed helicoidal stream surfaces. Consequently, the contributions to the shaft frequency loading calculated by the present computational procedure are given by the right-hand side of the following equation

$$\Delta P^{(1)} = \Delta P_o^{(1)} + \psi\, \Delta P_1^{(1)} \tag{2}$$

where $\Delta P_o^{(1)}$ is determined by executing PPEXACT with the measured wake as input, and $\Delta P_1^{(1)}$ is determined by exercising OBLIQUE and OBLIQ02. The program OBLIQ02 is required only if the measured wake has a significant second harmonic variation in the circumferential variations of the propeller inflow; therefore, for a propeller inclined in open-water OBLIQ02 is not needed.

The loading $\Delta P_1^{(1)}$ is the solution of the integral equation (1), where K_o is the same kernel computed by PPEXACT[3] for the blade frequency harmonic problem. Since the problem under consideration is linear, we may for convenience split (1) into two equations

$$\iint_s \Delta P_o^{(0)} K_1' \, ds = \iint_s (\Delta P_1^{(1)})_1 K_o \, ds \tag{3}$$

$$\iint_s \Delta P_o^{(2)} K_1'' \, ds = \iint_s (\Delta P_1^{(1)})_2 K_o \, ds \tag{4}$$

where $\Delta P_1^{(1)} = (\Delta P_1^{(1)})_1 + (\Delta P_1^{(1)})_2$. The program OBLIQUE solves (3) and OBLIQ02 solves (4).

A. Computational Procedure

The procedure described is intimately tied in with the already published program PPEXACT. Therefore, it is essential to have on hand the FORTRAN program and its user's manual, the four volumes cited as Reference 3. Familiarization with the usage of PPEXACT is assumed. Since it has been adequately documented elsewhere, the list of inputs used in executing PPEXACT for the sample case will be presented in the next section without further elaboration. The input data for OBLIQUE and OBLIQ02 will be described in an appropriate subsection after the list of steps in the procedure.

The list of steps are:

<u>Step 1</u>. Prepare the input data deck for PPEXACT in accordance with Reference 3 for the propeller and its measured inflow appropriately analyzed into harmonic components.

<u>Step 2</u>. Execute PPEXACT for the harmonic frequencies up to at least the second if the shaft frequency loading in inclinded flow is desired. The loadings are stored in a permanent file defined from the local file TAPE 3 in PPEXACT. This may be accomplished by the following control card

DEFINE (TAPE3 = SOLVECS)

where SOLVECS stands for solution vectors.

Step 3. Prepare input data deck for OBLIQUE in accordance with the subsection INPUT Data Deck.

Step 4. Execute OBLIQUE for the calculation of K_1' followed by the calculation of $(\Delta P_1^{(1)})_1$. The steady loadings, $\Delta P_o^{(0)}$, are read from the permanent file SOLVECS onto the local file TAPE9. This may be accomplished by the control card

GETPF (TAPE9 = SOLVECS)

Step 5. Prepare output data deck for OBLIQ02 in accordance with the subsection INPUT Data Deck.

Step 6. Execute OBLIQ02 for the calculation of K_1'' followed by the calculation of $(\Delta P_1^{(1)})_2$. The second harmonic loadings, $\Delta P_o^{(2)}$, are read from the permanent file SOLVECS onto the local file TAPE9 in the same manner as in Step 4.

Step 7. Combine results of Step 2, Step 4 and Step 6 to obtain the shaft frequency loading (or bending moments, etc.) due to the spatial distribution of inflow plus the distortion of the shed helicoidal stream surfaces behind the propeller using (2) to obtain:

$$\Delta P^{(1)} = \Delta P_o^{(1)} + \psi \{(\Delta P_1^{(1)}) + (\Delta P_1^{(1)})_2\} \tag{5}$$

The output of OBLIQUE is $\psi(\Delta P_1^{(1)})_1$ and the output of OBLIQ02 is $\psi(\Delta P_1^{(1)})_2$. Remember that the results are printed in the output in complex form. Collecting the real and imaginary parts of (5), we may write

$$\Delta P^{(1)} = R + iI$$

which may be reduced to the form

$$\Delta P^{(1)} = A \cos(\theta - \varphi) \tag{6}$$

where

$$A = \{R^2 + I^2\}^{\frac{1}{2}}$$
$$\varphi = \tan^{-1}\left(\frac{I}{R}\right)$$
θ = angular position of reference blade

Equation (6) is the result of interest for the shaft frequency response of a propeller's blade in a spatially varying inflow with the mean velocity inclined to the propeller shaft.

B. Tape OBLIQUE

The tape accompanying this document is inscribed OBLIQUE. It is a 650-foot magnetic tape guaranteed for use at 800 through 6250 bpi. The tape was created with the following control cards:

```
Job Card
User Card       Facility dependent controls
Charge Card
GETPF (OBLIQUE)
GETPF (OBLIQ02)
LABEL (TAPE, VSN = TXXX*, LB = KU, D = HD, NT, PO = W)
REWIND (TAPE)
COPYBF (OBLIQUE, TAPE)
COPYBF (OBLIQ02, TAPE)
UNLOAD (TAPE)
6/7/8/9  END-OF-FILE CARD
```

Therefore, the tape supplied is NOS unlabeled (LB = KU), where NOS is the operating system of the CDC 6600 computer at New York University on which the tape was made. The tape is 9-track (NT) and was used at 800 cpi (D = HD). Two files were copies (PO = W) onto the tape. The first file is OBLIQUE and the second file is OBLIQ02.

In order to mount and read (PO = R) the tape on another CDC 6000 series computer, the control cards required are:

```
Job
User        Facility dependent controls
Charge
DEFINE (TAPE1 = OBLIQUE)
DEFINE (TAPE2 = OBLIQ02)
LABEL (TAPE, VSN = TXXX*, LB = KU, D - HD, NT, PO = R)
REWIND (TAPE)
COPYBF (TAPE, TAPE1)
COPYBF (TAPE, TAPE2)
UNLOAD (TAPE)
6/7/8/9  END-OF-FILE CARD
```

Since the programs are in PL-Format, the following sequence of control cards are required to obtain a listing of the program:

```
Job
User        Facility dependent controls
Charge
GETPF (OLDPL = OBLIQUE)
UPDATE (F)
COPYSBF (COMPILE, OUTPUT)
7/8/9  END-OF-RECORD CARD
7/8/9  END-OF-RECORD CARD
6/7/8/9  END-OF-FILE CARD
```

where GETPF is equivalent to an ATTACH card. A similar sequence is required to list OBLIQ02, which is also in PL-Format.

In order to execute the created permanent files, the following sequence of cards are required.

---

*XXX is any integer from 1 to 999 which uniquely identifies the tape.

```
Job
User
Charge
GETPF (TAPE9 = SOLVECS)
REWIND (TAPE9)
GETPF (OLDPL = OBLIQUE)
UPDATE (F)
FTN (I, ER)
RFL, 200000.
LGO.
7/8/9  END-OF-RECORD CARD
7/8/9  END-OF-RECORD CARD
INPUT DATA DECK
6/7/8/9 END-OF-FILE CARD
```

A similar sequence of cards is required to execute OBLIQ02 (the only card to be changed is the card with OLDPL = OBLIQUE which is changed to OLDPL = OLBIQ02). Both programs require the permanent file created by the DEFINE (TAPE3 = SOLVECS) control card during the execution of PPEXACT.

C. INPUT Data Deck

The first data card required by OBLIQUE and OBLIQ02 is described as follows:

1. Control for OBLIQUE or OBLIQ02

Columns	Format	Variable Name	Entry
1-5	I	NPSI	= 0 Noninclined inflow = 1 Inclined inflow
6-15	F	ANGLE	Angle of shaft inclination with inflow, ψ
16-20	I	NIY	position of desired loadings in the queue of solution vectors on TAPE9; 1 for ΔP_o^o, or 3 for ΔP_o^2
21-25	I	NIY1	position of blade loadings in the queue of solution vectors on TAPE9; 2 for ΔP_o^1

The next 22 cards are identifical with the input to PPEXACT for the determination of the shaft frequency loading as described in Reference 3. The input may be extracted from the input data deck used to execute PPEXACT, which is a prerequisite to this calculation.

D. OUTPUT

The output format of OBLIQUE and OBLIQ02 is identical with that of PPEXACT. The only important piece of information to keep in mind is that the output of OBLIQUE is due to the left-hand-side of (3) and the output of OBLIQ02 is due to the left-hand-side of (4) both of which are not results of the measured wake data. The latter effect was already computed by PPEXACT. Again, the reader is referred to the theoretical considerations described in Reference 1 for details of this analysis.

SAMPLE CASE

The sample case as described in Reference 1 demonstrates that the distortion of the shed helicoidal stream surfaces in the wake of the propeller are 180 degrees out of phase with the primary contributor to the shaft frequency loading, viz, the across-the disk component of the oncoming flow.

In order to execute the programs for this calculation the input data decks are presented in Tables 1 through 3. Table 1 lists the input data used to execute PPEXACT. Table 2 was used to execute OBLIQUE and Table 3 was used to execute OBLIQ02. The results are presented in Table 4 illustrating the effects of each component. See Reference 1 for an elaboration of these results.

The execution time of PPEXACT for six frequencies of loading is approximately 10 systems minutes on the CDC 6600 computer. The program OBLIQUE and OBLIQ02 take approximately 12 systems minutes each on the same computer. Therefore, the total execution time for the

problem of computing blade bending moments including the contribution of inflow inclination on the shaft frequency loading is approximately 34 systems resource minutes on the CDC6600.

REFERENCES

1. Valentine, D. T.: "Linearized Unsteady Lifting Surface Theory of a Lightly Loaded Propeller in an Inclined Flow," Stevens Institute of Technology, Davidson Laboratory, Report SIT-DL-79-9-2064, August 1979.

2. Tsakonas, S., Jacobs, W. and Ali, R.: "An 'Exact' Linear Lifting-Surface Theory for a Marine Propeller in a Nonuniform Flow Field," Journal of Ship Research, Vol. 17, No. 4, December 1973, pp. 196-207.

3. Tsakonas, S., Jacobs, W. and Ali, R.: "Documentation of a Computer Program for the Pressure Distribution, Forces and Moments on Ship Propellers in Hull Wakes," Stevens Institute of Technology, Davidson Laboratory, Report No. SIT-DL-76-1863, four volumes, 1976.

TABLE 1

INPUT INFORMATION TO PPEXACT AS PRINTED IN OUTPUT

(See Reference 3 for Description)

a. Propeller data and options selection

```
FF-1088 PROPELLER      EAR=   .330   P/D=  1.061    DESIGN J=    .767    RPM=240.000
                       SHIP SPEED= 47.258   NO OF BLADES=  5.    PROP DIAM=15.000
```

PROPELLER PARAMETERS

```
   1     0     0     0     0     0     0
   5     8     5    11     2    17
 4.00320    .33300    .08900   1.99000  47.25900   7.50000    .33300   0.00000
  .00536    .01425    .02060    .02544    .02924    .02357    .02019   -.00203
  .44277    .48596    .51753    .54275    .56077    .55661    .51223    .41768
  .77321    .66990    .58688    .51734    .45676    .40134    .34338    .29749
 3.10500   3.96000   4.80000   5.61000   6.45000   7.11000   6.91500   6.33000
```

COMPUTATION FOR OTHER THAN NACA A-MEAN LINES

b. Mean Wake taken to be zero in sample case - uniform inflow

WAKE ID 1

ORDER OF BLADE HARMONIC OF KERNEL= 0 ORDER OF BLADE HARMONIC OF LEFT HAND SIDE= 0

NORMAL WAKE VELOCITY

SPAN-LOCATION	REAL	IMAGINARY
.333	0.00000	0.00000
.422	0.00000	0.00000
.511	0.00000	0.00000
.600	0.00000	0.00000
.689	0.00000	0.00000
.778	0.00000	0.00000
.867	0.00000	0.00000
.956	0.00000	0.00000

c. Flow angle contribution was computed in sample case

d. Camber is approximated by sine squared distribution

ORDER OF BLADE HARMONIC OF KERNEL= 0

KERNEL MATRIX BY BIRNBAUM APPROACH

LEADING-EDGE-RADIUS/CHORD

.01980	.00764	.00360	.00122	.00050	.00022	.00011	.00010

SINE SQUARED

.00523	.00570	.00528	.00456	.00374	.00285	.00190	.00076
.00990	.01080	.01001	.00864	.00709	.00540	.00360	.00144
.01403	.01530	.01417	.01224	.01005	.00765	.00510	.00204
.01760	.01920	.01779	.01536	.01261	.00960	.00640	.00256
.02063	.02250	.02084	.01799	.01478	.01126	.00751	.00300
.02310	.02520	.02335	.02015	.01655	.01261	.00841	.00336
.02503	.02730	.02529	.02183	.01793	.01366	.00911	.00364
.02640	.02880	.02668	.02303	.01892	.01441	.00961	.00384
.02723	.02970	.02751	.02375	.01951	.01486	.00991	.00396
.02750	.03000	.02779	.02399	.01971	.01501	.01001	.00400
.02723	.02970	.02751	.02375	.01951	.01486	.00991	.00396
.02640	.02880	.02668	.02303	.01892	.01441	.00961	.00384
.02503	.02730	.02529	.02183	.01793	.01366	.00911	.00364
.02310	.02520	.02335	.02015	.01655	.01261	.00841	.00336
.02063	.02250	.02084	.01799	.01476	.01126	.00751	.00300
.01760	.01920	.01779	.01536	.01261	.00960	.00640	.00256
.01403	.01530	.01417	.01224	.01005	.00765	.00510	.00204
.00990	.01080	.01001	.00864	.00709	.00540	.00350	.00144
.00523	.00570	.00528	.00456	.00374	.00285	.00190	.00076

e. Wake data for the first and second harmonic of loading

WAKE ID 2

ORDER OF BLADE HARMONIC OF KERNEL= 1   ORDER OF BLADE HARMONIC OF LEFT HAND SIDE= 1

NORMAL WAKE VELOCITY

SPAN-LOCATION	REAL	IMAGINARY
.333	-.05210	.08640
.422	-.03290	.08550
.511	-.01640	.08670
.600	-.00480	.08430
.689	.00330	.07880
.778	.00820	.06090
.867	.00830	.04510
.956	.00270	.03670

WAKE ID 3

ORDER OF BLADE HARMONIC OF KERNEL= 2   ORDER OF BLADE HARMONIC OF LEFT HAND SIDE= 2

NORMAL WAKE VELOCITY

SPAN-LOCATION	REAL	IMAGINARY
.333	-.07250	-.00710
.422	-.05720	-.00380
.511	-.04140	-.00070
.600	-.02880	.00110
.689	-.02000	.00180
.778	-.01970	-.00110
.867	-.01910	-.00260
.956	-.01620	-.00160

TABLE 2

SAMPLE INPUT DATA DECK FOR PROGRAM OBLIQUE

```
    1  10.4          1     2
 AUGUST 1978
 FF-1088 PROPELLER  0.830      1.061      0.767
 240.0     47.258    5.0        15.0
    0     0    0     0    0     0    0
    8     5    5    17   11     2
4.0032     0.333     0.089      1.990      47.258     7.5        0.333      0.0
0.0        1.0       25.0
0.00536    0.01425   0.02060    0.02544    0.02924    0.02857    0.02019    -.00203
0.44277    0.48596   0.51753    0.54275    0.56077    0.55661    0.51223    0.41768
0.77321    0.66990   0.58688    0.51734    0.45676    0.40134    0.34838    0.29749
3.105      3.960     4.800      5.610      6.450      7.110      6.915      6.330
    1     1    0     0    0
-0.0520    0.0864
-0.0329    0.0855
-0.0164    0.0867
-0.0048    0.0843
0.0033     0.0788
0.0082     0.0609
0.0083     0.0451
0.0027     0.0367
    1     0    0     0    0     0    0
0.019      0.00704   0.0030     0.00122    0.00050    0.00022    0.00011    0.00010
```

TABLE 3

SAMPLE INPUT FOR PROGRAM OBLIQ02

```
    1  10.4           3     2
 AUGUST 1978
 FF-1088 PROPELLER  0.830      1.061      0,767
 240.0     47.258    5.0        15.0
    0     0     0     0     0     0     0
    8     5     5    17    11     2
4.0032    0,333     0.089      1,990      47,258     7.5       0,333     0.0
0.0       1,0       25,0
0.00536   0,01425   0.02060    0,02544    0,02924    0,02857   0.02019   -.00203
0.44277   0,48596   0.51753    0,54275    0,56077    0,55661   0.51223   0.41768
0.77321   0,66990   0.58688    0,51734    0,45676    0.40134   0.34838   0.29749
3.105     3.960     4.800      5.610      6.450      7.110     6.915     6.330
    1     1     0     0     0
-0.0520   0,0864
-0.0329   0,0855
-0.0164   0,0867
-0.0048   0,0843
0.0033    0,0788
0.0082    0,0609
0.0083    0,0451
0.0027    0,0367
    1     0     0     0     0     0     0
0.019     0,00704   0.0030     0.00122    0,00050    0,00022   0.00011   0.00010
```

TABLE 4

RESULTS OF SAMPLE CALCULATION

Shaft Frequency Blade Bending Moment

Coefficients, $\tilde{K}^{(1)}_{M_b} = \tilde{M}^{(1)}_b/(\rho n^2 D^5)$

Non-dimensional Propeller Radius (r/r_o)	$\tilde{K}^{(1)*}_{M_{b_o}}$	$\varphi^{(1)*}_o$ (deg)	$\tilde{K}^{(1)**}_{M_{b_1}}$	$\varphi^{(1)}_1$ (deg)	$\tilde{K}^{(1)***}_{M_{b_2}}$	$\varphi^{(1)}_2$ (deg)
	Components of Calculated Blade Bending Moments					
0.333	0.00121	100.8	.00027	-2.8	0.000058	165.6
0.421	0.00094	99.7	.00013	10.6	.000055	160.9

---

*Contribution due to shaft frequency harmonic of hull wake.

**Contribution due to ΔP^o_o and K'_1.

***Contribution due to ΔP^2_o and K''_1.